Modelling Weather Conditions in the Port Area and in the Coastal Zone of Tiksi Bay

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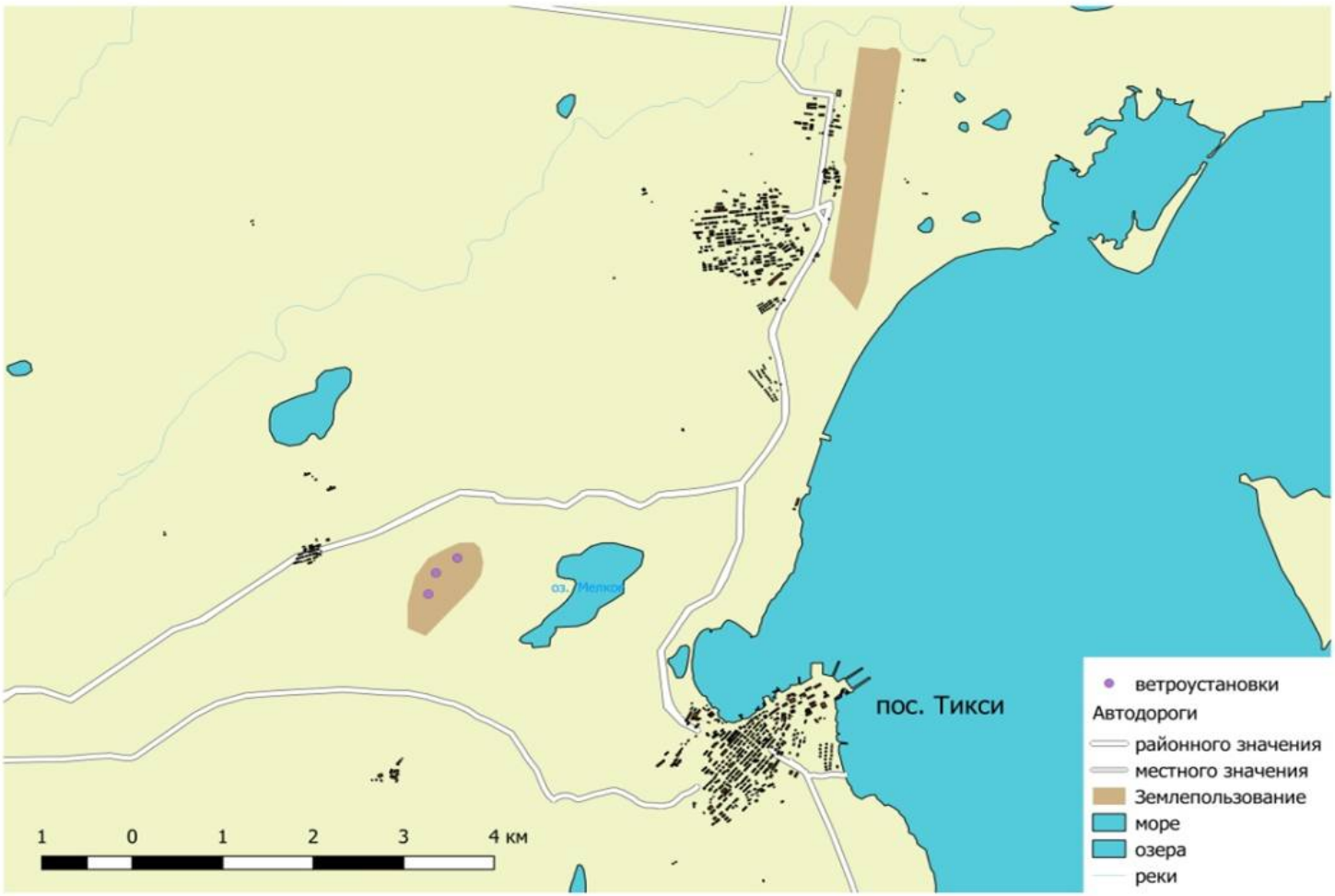
Introduction

New wind farms in Russia:

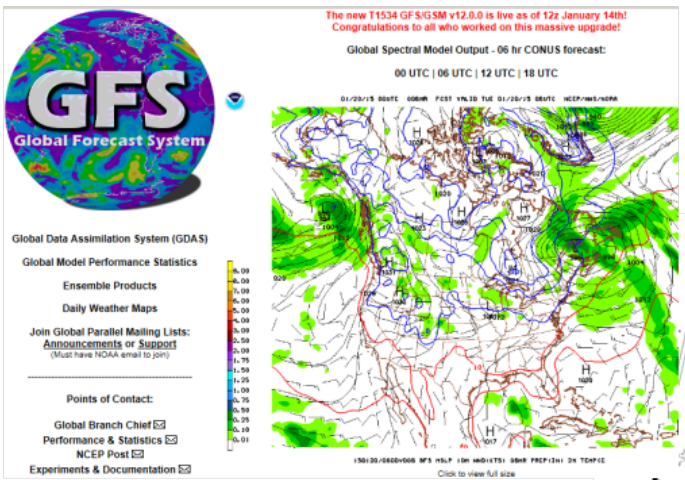
- Republic of Adygea
- The Republic of Sakha
- Stavropol Territory
- The Rostov Region
- The Murmansk Region

Map of Tiksi Village. Open Street Map



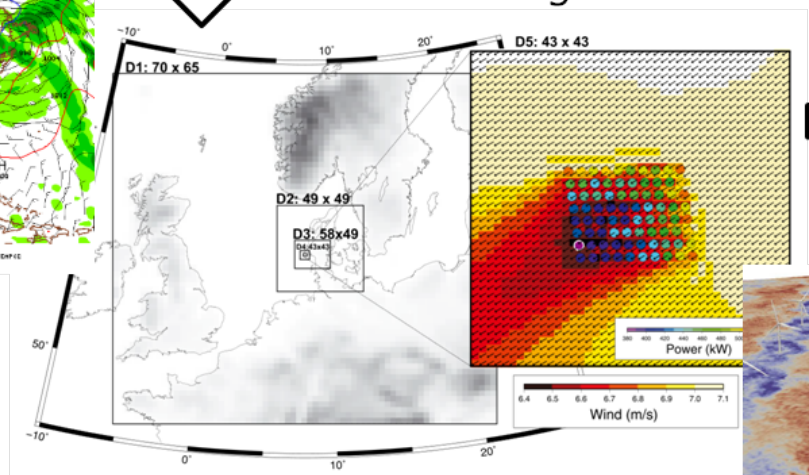
How to Study the Wind Farms

Macroscale → Mesoscale → Microscale

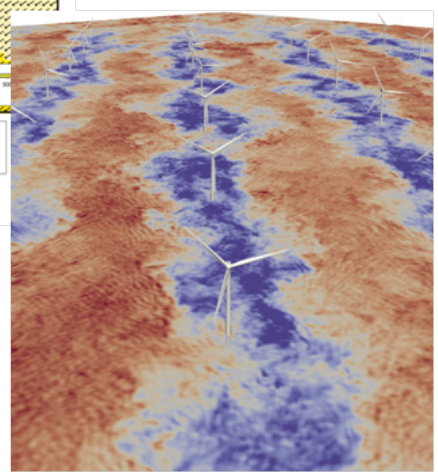


Global Forecast System

Weather Research and Forecasting



Simulator fOr Wind Farm Applications



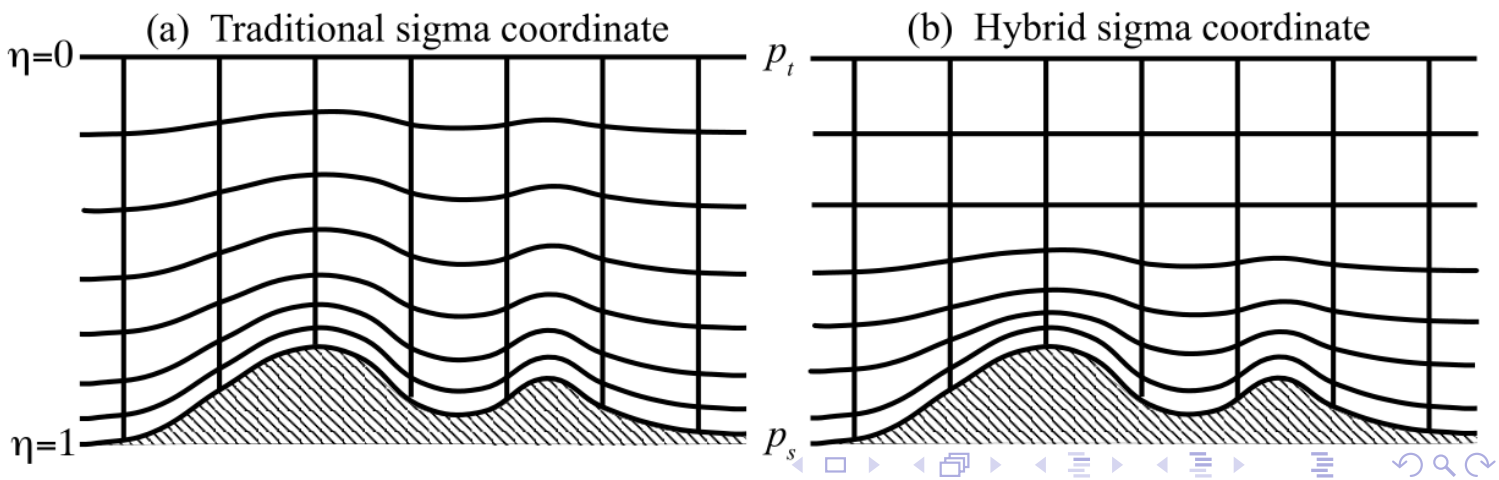
Vertical Coordinate

The ARW equations are formulated using a terrain-following hydrostatic-pressure vertical coordinate denoted by η, which is also referred to a mass vertical coordinate.

- WRF-ARW version 3: $\eta = \dfrac{p_d - p_t}{p_s - p_t}$, (a)
- **WRF-ARW version 4**:

  $p_d = B(\eta)(p_s - p_t) + [\eta - B(\eta)](p_0 - p_t) + p_t$, (b)

where p_d is the hydrostatic component of the pressure of dry air, and p_s and p_t refer to values of p_d along the surface and top boundaries, respectively. To smoothly transition from a sigma coordinate near the surface to a pressure coordinate at upper levels, $B(\eta)$ is defined by a third order polynomial.

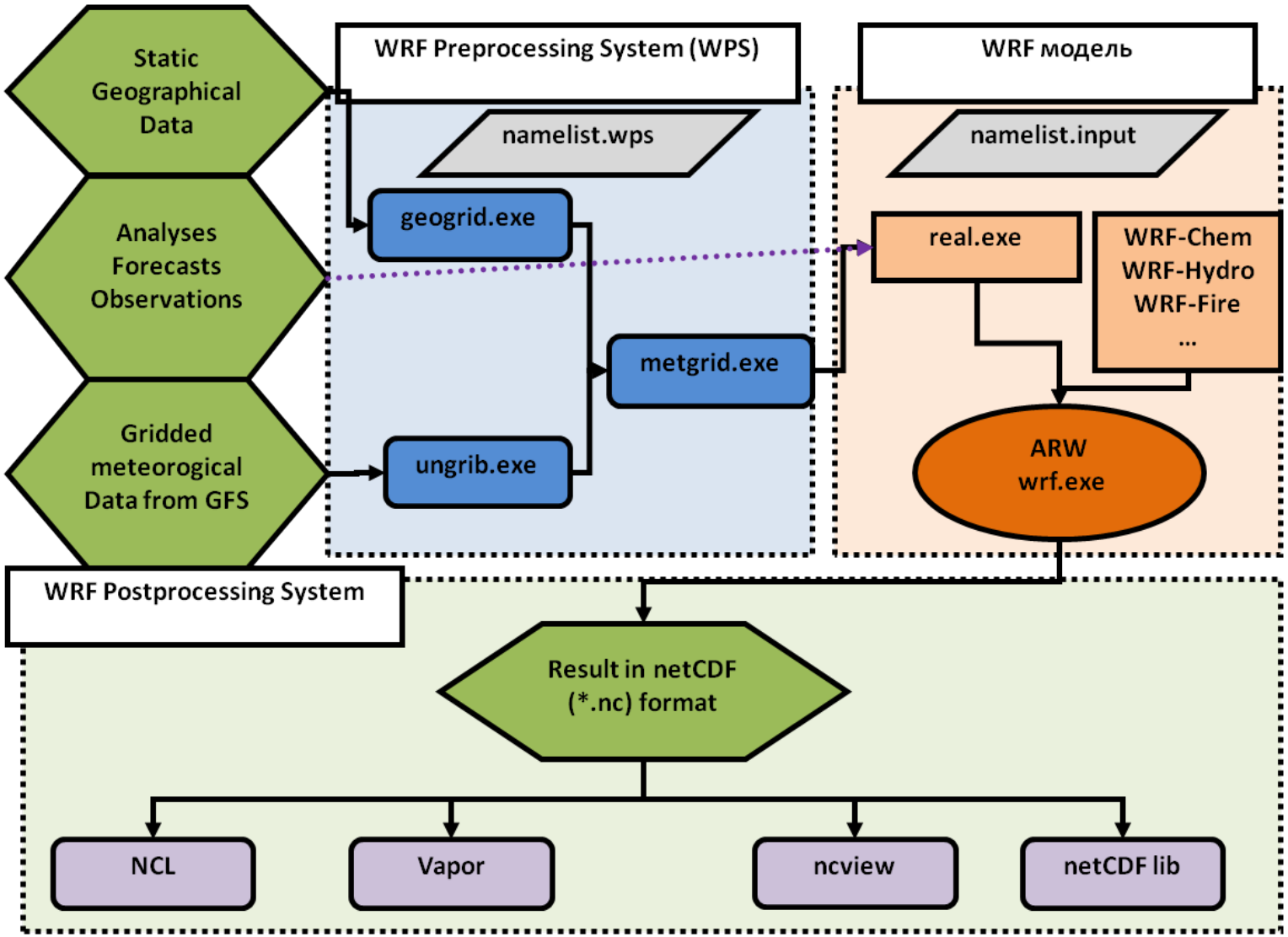


WRF-ARW Mathematical Model

Fully-compressible, Eulerian nonhydrostatic equations solver with a run-time hydrostatic option available. Conserves dry air mass and scalar mass.

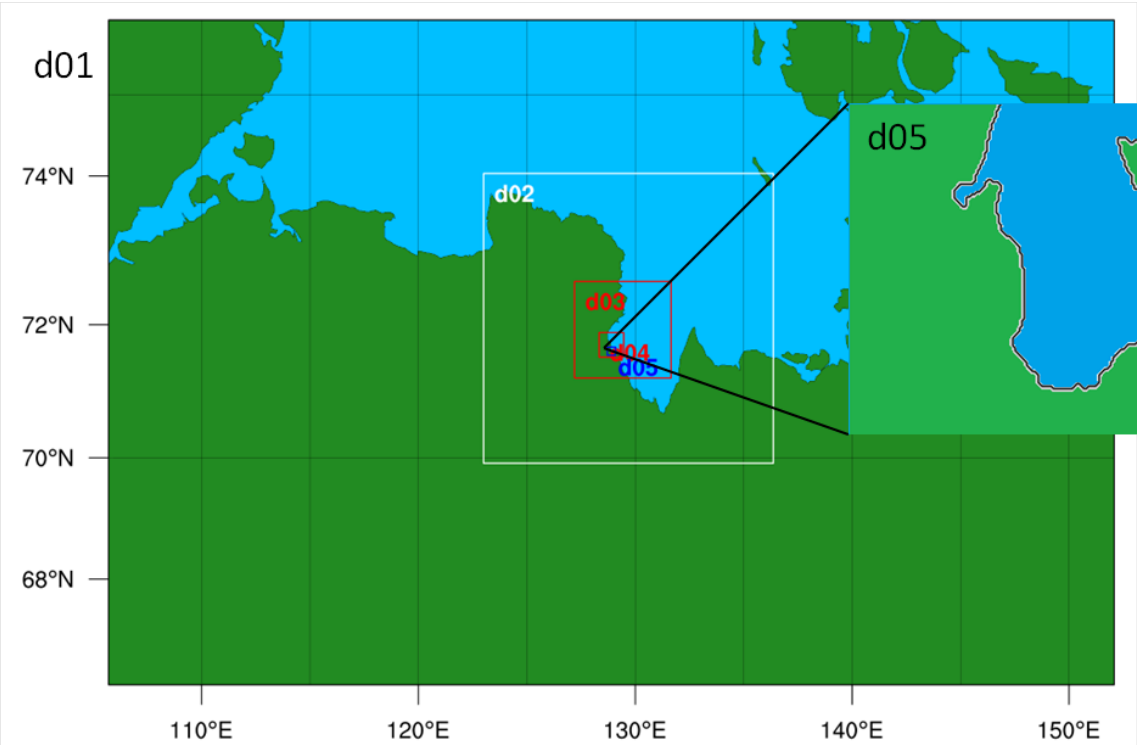
$$\partial_t U + m[\partial_x(Uu) + \partial_y(Vu)] + \partial_\eta(\Omega u) \tag{1}$$
$$+ (\alpha/\alpha_d)[\mu_d(\partial_x\phi' + \alpha_d\partial_x p' + \alpha'_d\partial_x\overline{p}) + \partial_x\phi(\partial_\eta p' - \mu'_d)] = F_U;$$
$$\partial_t V + m[\partial_x(Uv) + \partial_y(Vv)] + \partial_\eta(\Omega u) \tag{2}$$
$$+ (\alpha/\alpha_d)[\mu_d(\partial_y\phi' + \alpha_d\partial_y p' + \alpha'_d\partial_y\overline{p}) + \partial_y\phi(\partial_\eta p' - \mu'_d)] = F_V;$$
$$\partial_t W + m[\partial_x(Uw) + \partial_y(Vw)] + \partial_\eta(\Omega w) \tag{3}$$
$$- m^{-1}g(\alpha/\alpha_d)[\partial_\eta p' - \overline{\mu}_d(q_v + q_c + q_r)] + m^{-1}\mu'_d g = F_W;$$
$$\partial_t\mu'_d + m^2[\partial_x U + \partial_y V] + m_y\partial_\eta\Omega = 0; \tag{4}$$
$$\partial_t\phi' + \mu_d^{-1}[m^2(U\partial_x\phi + V\partial_y\phi) + m\Omega\partial_\eta\phi - mgW] = 0; \tag{5}$$
$$\partial_t\Theta_m + m^2[\partial_x(U\theta_m) + \partial_y(V\theta_m)] + m\partial_\eta(\Omega\theta_m) = F_{\Theta_m}; \tag{6}$$
$$\partial_t Q_m + m^2[\partial_x(Uq_m) + \partial_y(Vq_m)] + m\partial_\eta(\Omega q_m) = F_{Q_m}. \tag{7}$$

WRF-ARW Operation Scheme



Tiksi. Problem Statement

Domains Used in the WRF Simulation



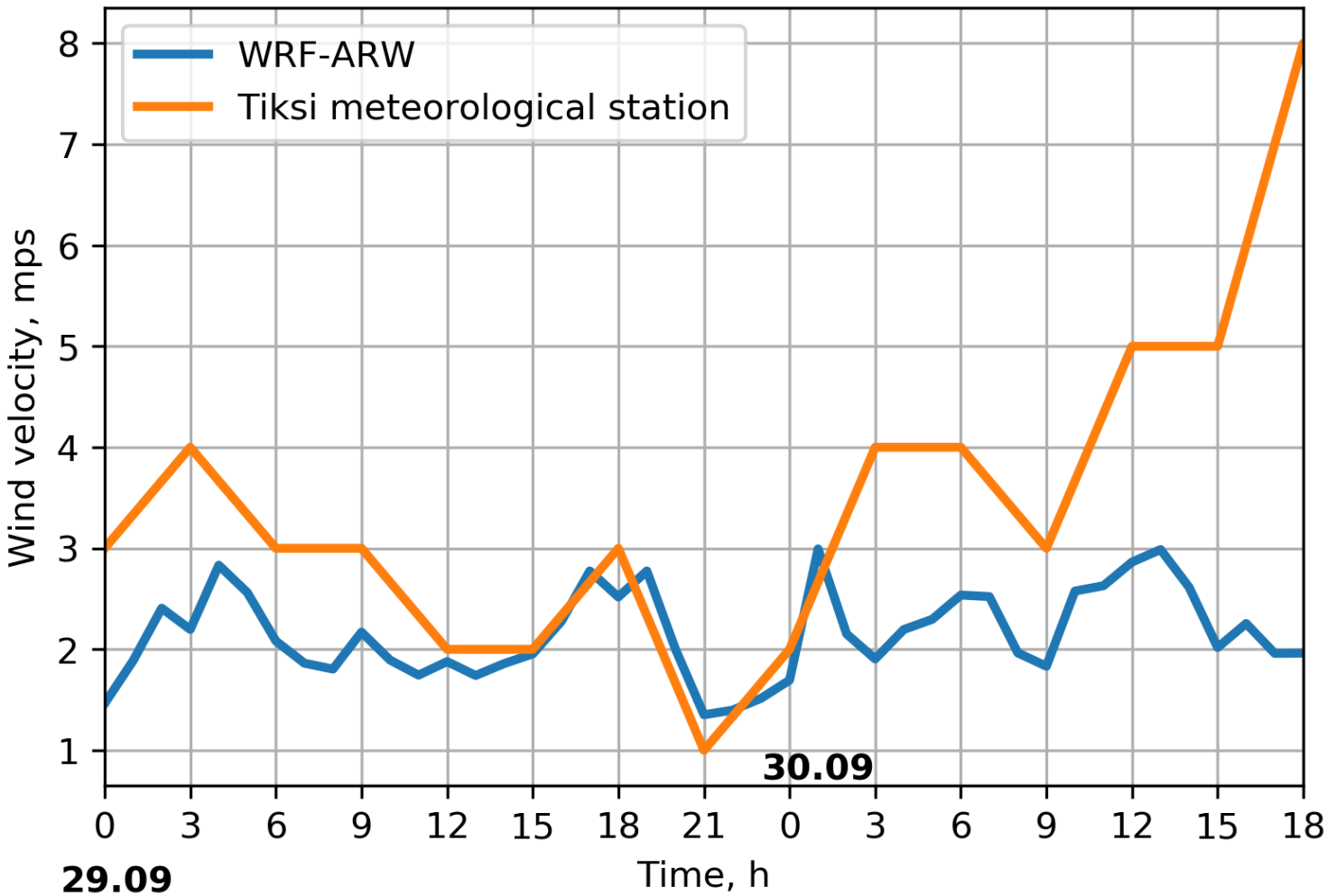
Domain	Center coordinates	Grid resolution	Spatial step
d01 (main)	$71°36'\text{N}, 128°54'\text{E}$	60×40	27 km
d02	$72°5'23''\text{N}, 129°41'9''\text{E}$	52×52	9 km
d03	$71°55'4''\text{N}, 129°25'26''\text{E}$	52×52	3 km
d04	$71°42'36''\text{N}, 128°54'\text{E}$	40×40	1 km
d05	$71°37'6''\text{N}, 128°54'\text{E}$	40×40	333 m

WRF Model Parameterization

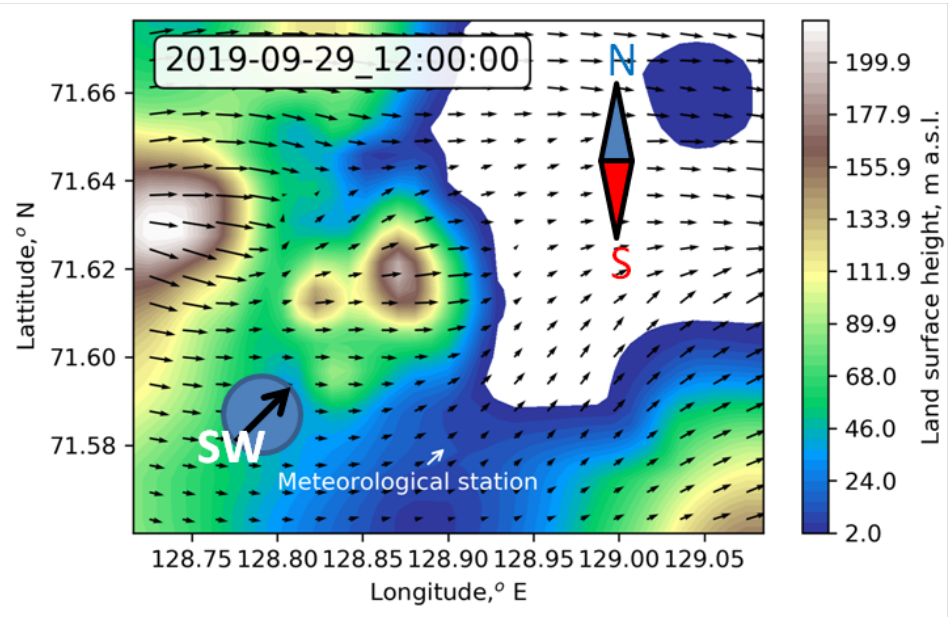
- 33 vertical levels.
- Simulation run 66 hours, time period: 28.09.2019 00:00 – 30.09.2019 18:00. The first 24 hours is a spin up of the model.
- Microphysics – Thompson scheme;
- Cumulus parameterization option – Kain-Fritsch (new Eta) scheme in the outermost three domains: d01, d02, d03. In d04 and d05 there is no parameterization;
- The shortwave and longwave radiation schemes are Dudhia and RRTMG scheme, respectively; Planetary Boundary layer – Mellor-Yamada-Janjic scheme;
- Surface Layer – Monin-Obukhov (Janjic) scheme;
- Land-surface option – Unified Noah land-surface model;
- η-levels: 1.000, 0.997, 0.989, 0.981, 0.969, 0.956, 0.939, 0.918, 0.893, 0.863, 0.829, 0.791, 0.749, 0.705, 0.658, 0.610, 0.561, 0.512, 0.463, 0.412, 0.363, 0.314, 0.268, 0.223, 0.182, 0.144, 0.113, 0.086, 0.064, 0.045, 0.029, 0.016, 0.005, 0.000. Time step for the coarse domain – 2.5 minutes.

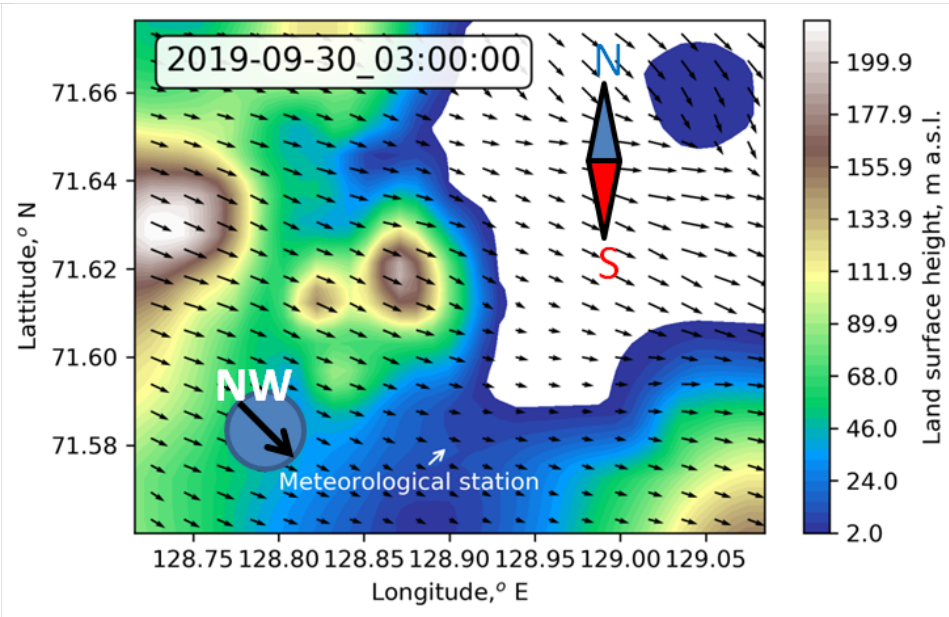
Comparison of wind speed

at the location of Tiksi weather station for model and real data



Wind Distribution on the Land Surface

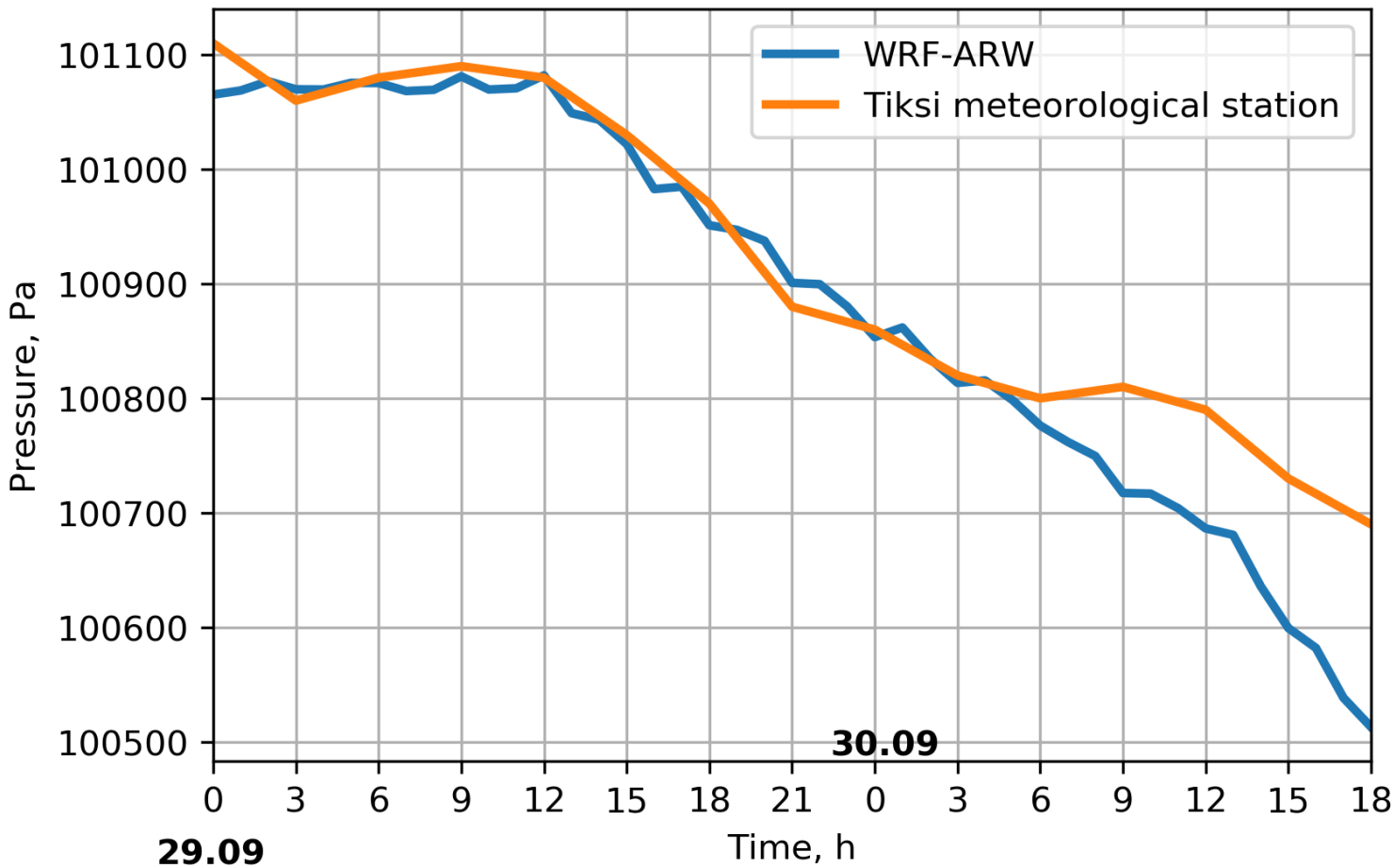




Time UTC	Date	Wind Direction (from)	Velocity, m/s
12	29.09	SW	2
3	30.09	NW	4

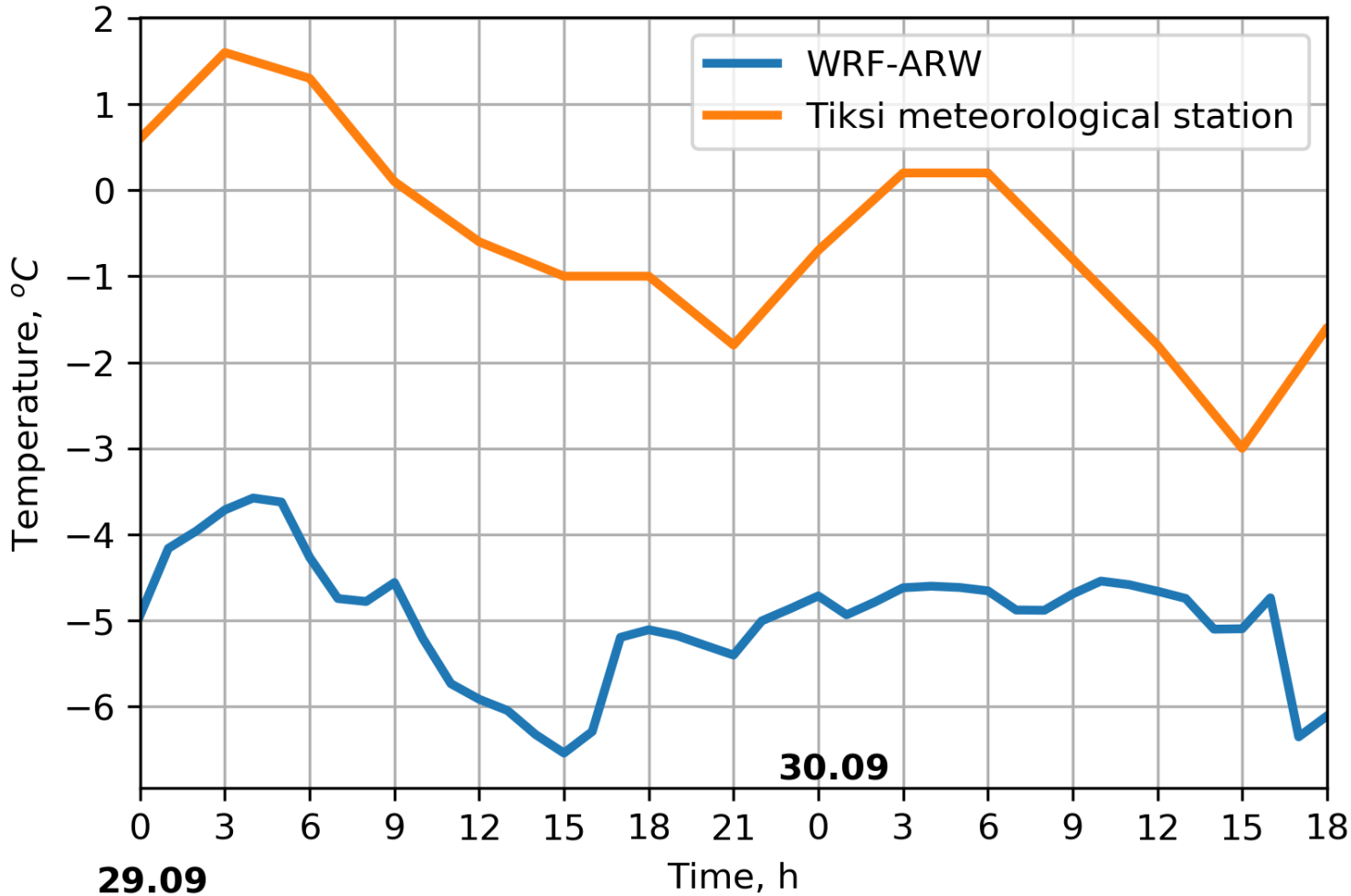
Comparison of atmospheric pressure

at the location of Tiksi weather station for model and real data



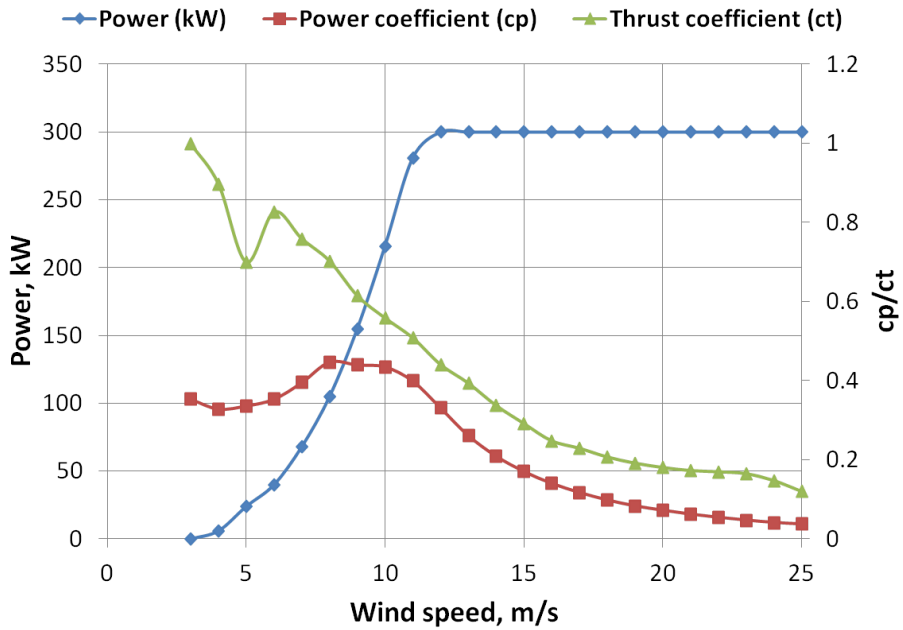
Comparison of temperature

at the location of Tiksi weather station for model and real data

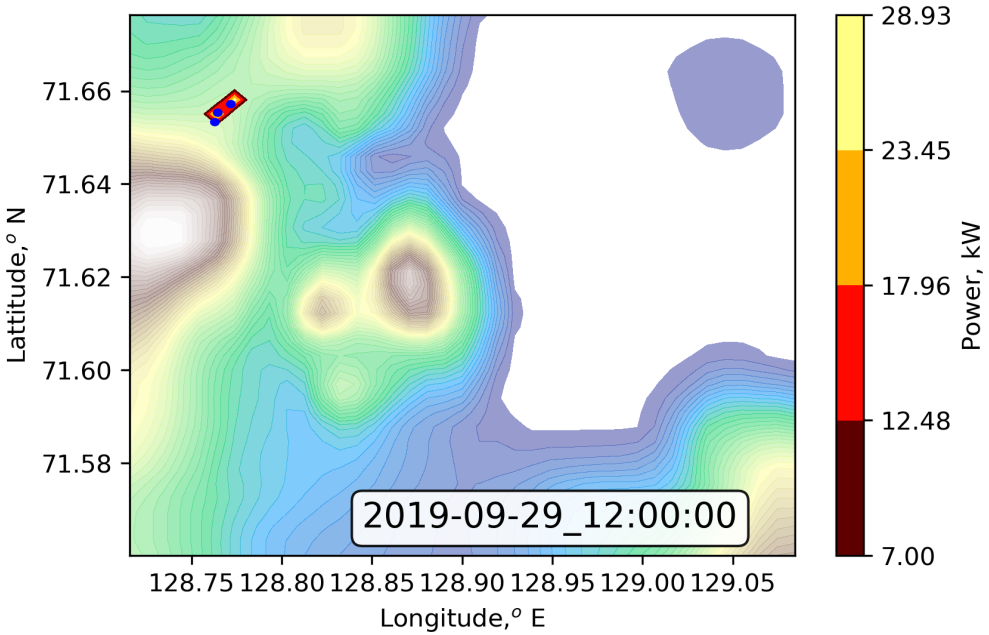


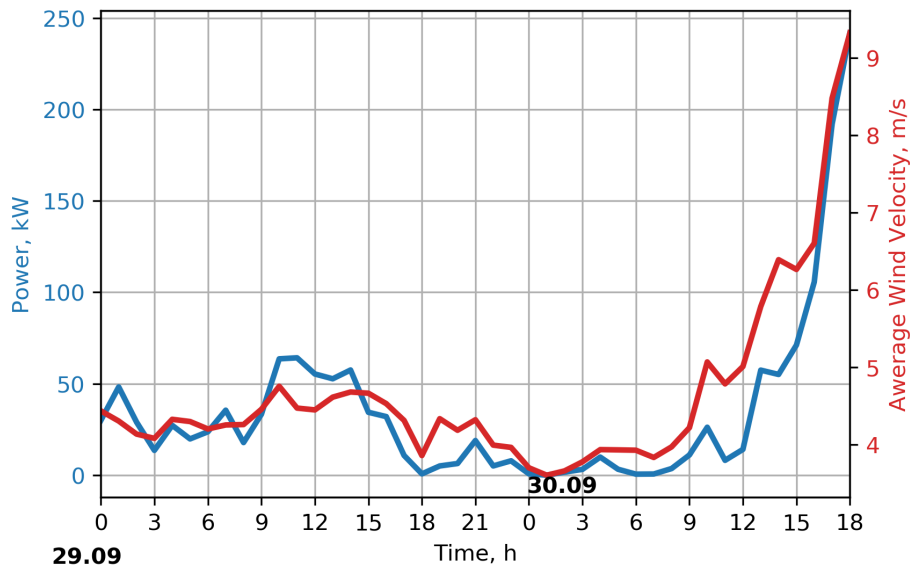
Tiksi Wind Farm

- 3 wind turbines
- Komaihaltec KWT300 (Japan)
- Rated power: 300.0 kW
- Diameter: 33.0 m
- Hub height: 41.5 m

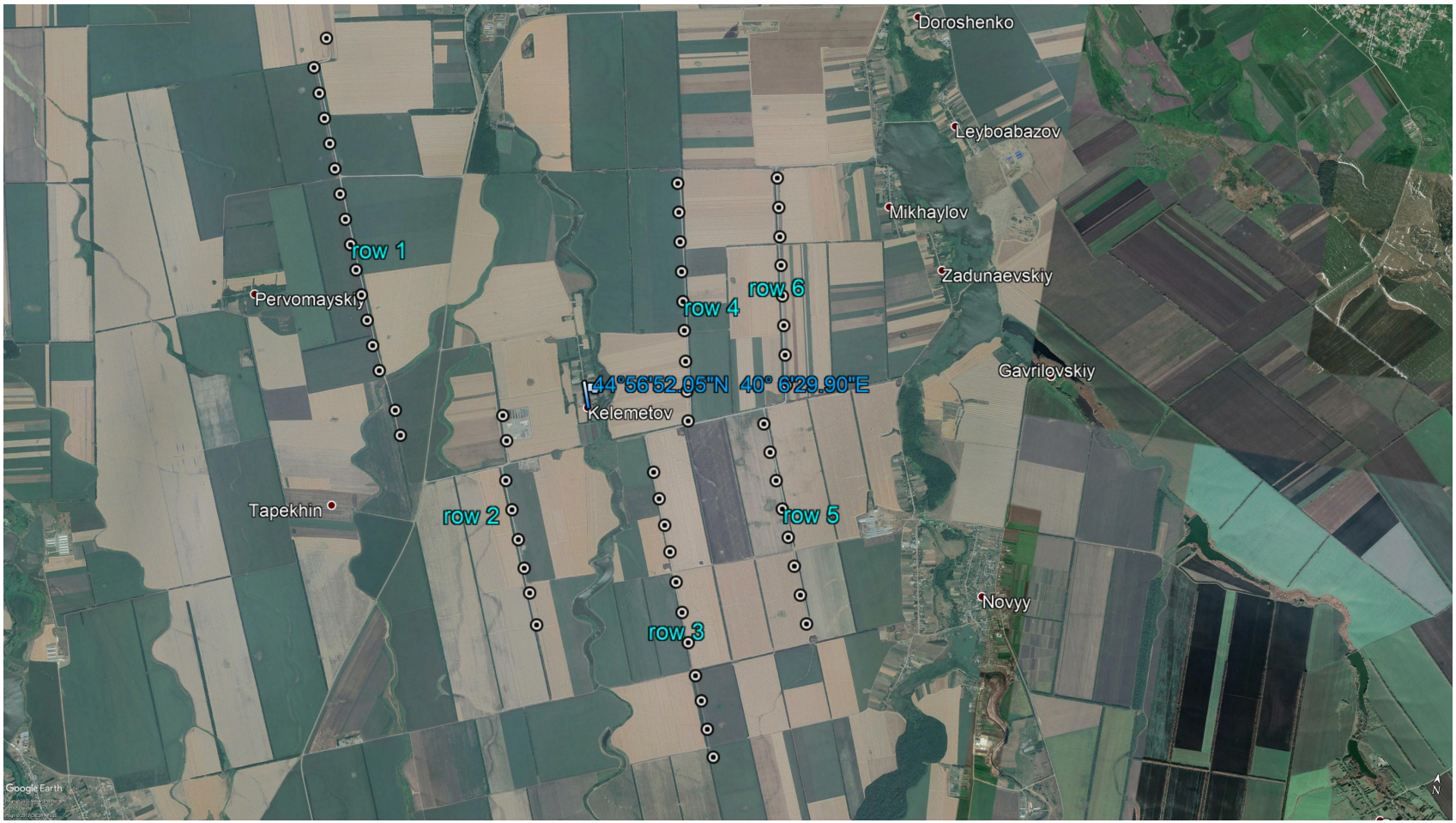


Tiksi Wind Farm



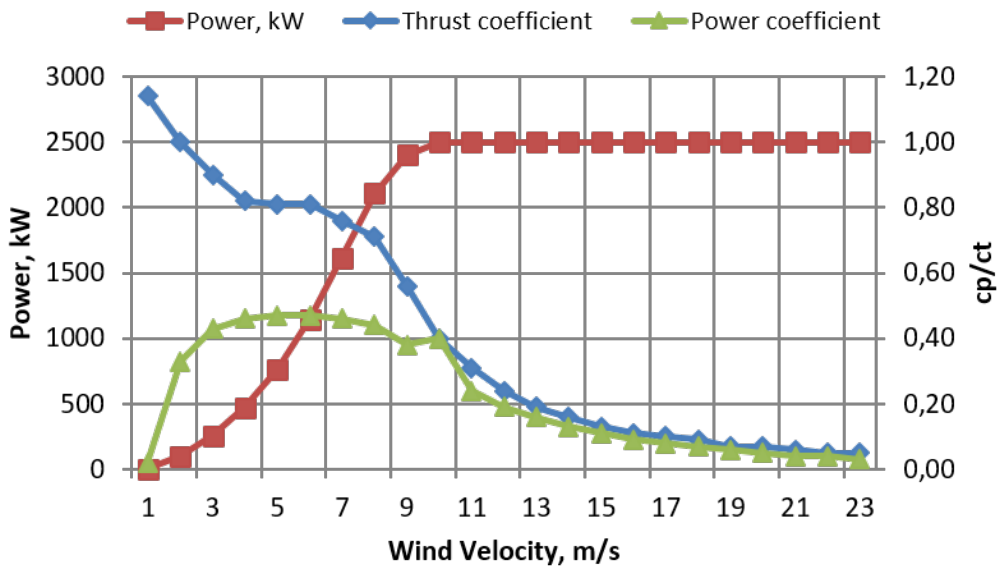


Adygea Wind Farm

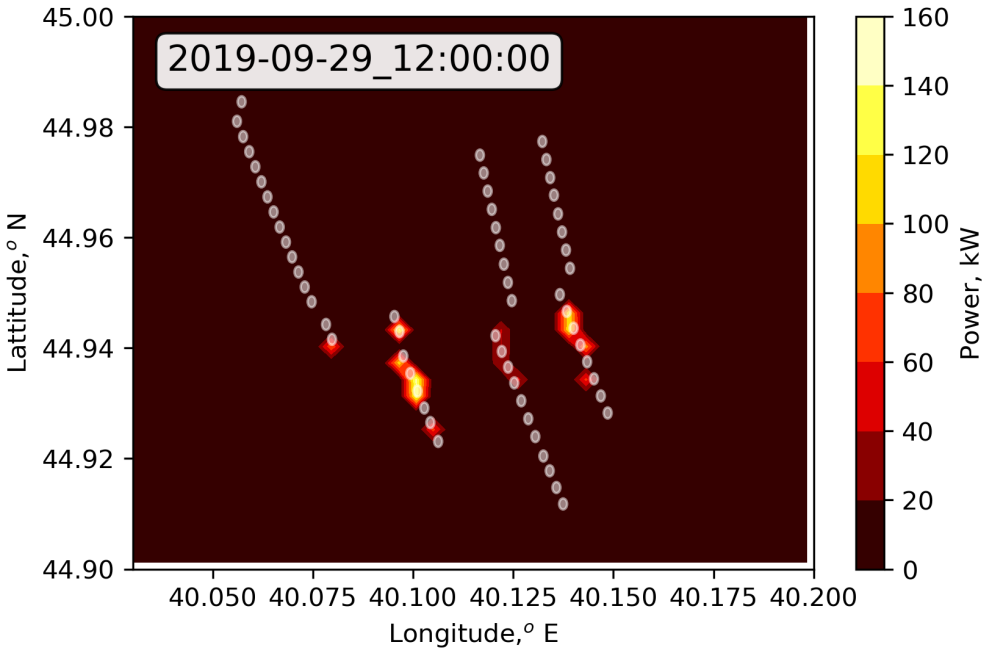


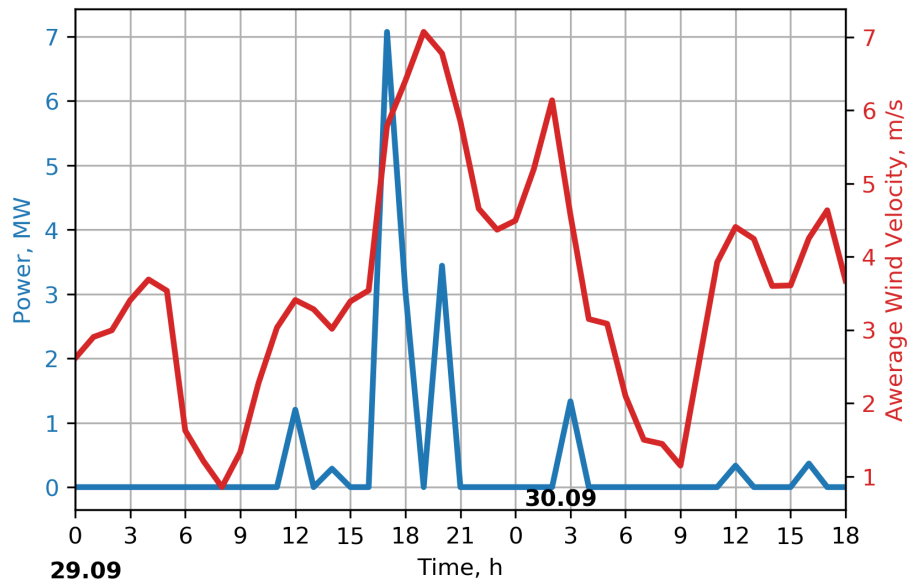
AdygeaWind Farm

- 60 wind turbines
- Nowawind L100 (Russia)
- Rated power: 2.5 MW
- Diameter: 100 m
- Hub height: 99 m



Adygea Wind Farm





Conclusions

- WRF-ARW package was installed and tested
- GFS model was used for initial and boundary conditions
- Good agreement of results with data from meteorological station for pressure and wind velocity
- Test configurations of wind farms (location and wind turbines parameters)
- Test cases of Tiksi and Adygea wind farms were run with 12 cores during 4-5 hours (for calculating dates: 28.09.19 00:00 – 30.09.19 18:00, 66 hours)
- We have obtained power distribution for two wind farms
- Need better physical parameterization of WRF-ARW model for Tiksi

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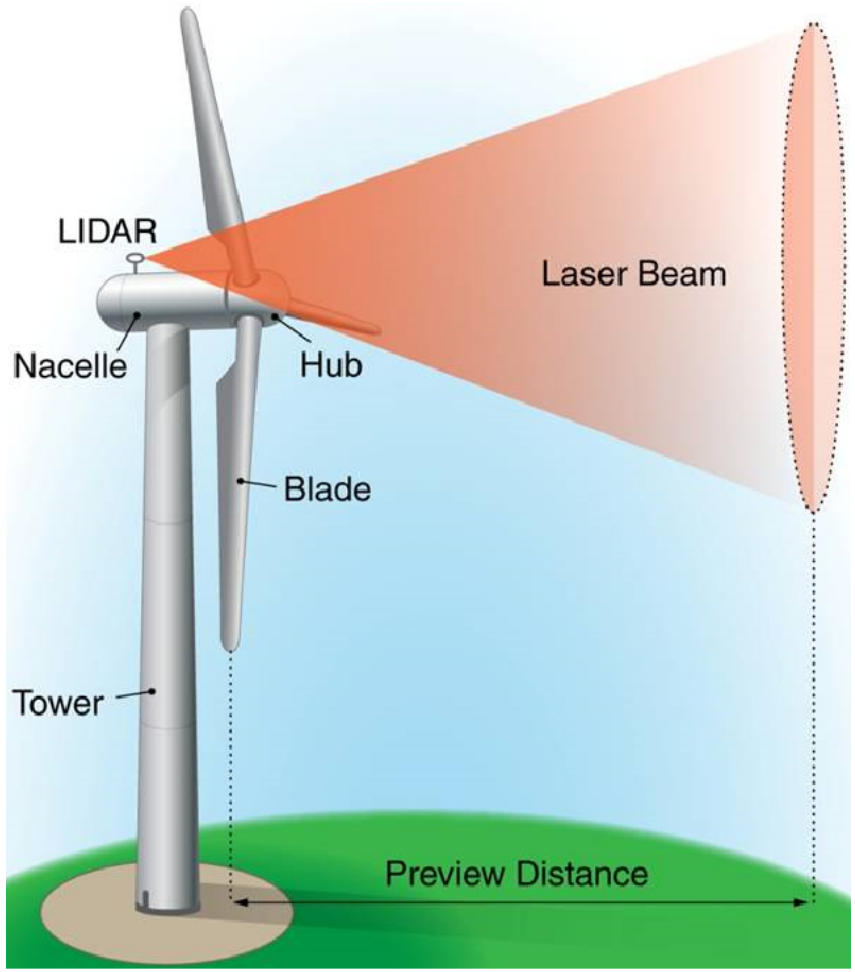
Additional Slides

LiDAR

Application

- power performance assessment
- wind farm performance optimization
- wind resource / loads assessment
- wake analysis



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